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AN INDUSTRIAL WASTE GUIDE TO THE MILK PROCESSING INDUSTRY

Public Health Service
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an Industrial Waste Guide to the

Milk Processing Industry

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

an Industrial Waste Guide to the

Milk Processing Industry

Prepared by

Subcommittee on Dairy Waste Disposal

Dairy Industry Committee, in Cooperation

With the National Technical Task

Committee on Industrial Wastes

For the

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

I

Foreword

In the Dairy Industry, as in many other industries, control and disposal of wastes is a major concern of many plants. Optimum utilization and reduction of wastes is essential for most economic production in small as well as large plants. Wastes which cannot be eliminated must be disposed of in a suitable manner. Protecting the Nation's limited water resources for maximum use is mutually beneficial to industry, other special groups, individual citizens, and the nation as a whole. In recognition of this fact, industries are paying increasing attention to disposing of their wastes in a manner which will not impair the utility of stream waters for other beneficial uses.

This *Waste Guide to the Milk Processing Industry* is intended primarily to aid operators of milk processing and handling establishments to utilize, reduce, and otherwise suitably dispose of their wastes.

It was prepared by the Sub-Committee on Dairy Waste Disposal of the Dairy Industry Committee which is a trade organization of the entire Dairy Industry. It was submitted to the Public Health Service through the Dairy Industry representative on the National Technical Task Committee on Industrial Wastes.

The National Technical Task Committee on Industrial Wastes is composed of representatives from the Nation's leading industries concerned with solving difficult industrial waste problems. The objective of the organization is to perform technical tasks pertaining to industrial wastes in cooperation with the Public Health Service and all others concerned with improving the quality of our water resources. The preparation of this Guide was one of the tasks assumed by the Dairy Industry in carrying out this objective.

This is the first of a series of Industrial Waste Guides which will be prepared by the National Technical Task Committee in cooperation with the Public Health Service.

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Abstract

A plant handling or processing milk and its products may be generally classified as a receiving station, bottling plant, cheese factory, creamery, condensery, dry-milk plant or ice cream plant.

Dairy plant wastes are made up, for the most part, of various dilutions of whole milk, separated milk, buttermilk and whey from accidental or intentional spills; drippings allowed to waste by inefficient processing equipment, methods or operations; washes containing alkali or other chemicals used to remove milk, milk products and partially caramelized materials from cans, bottles, tanks, vats, utensils, pipes, pumps, hot wells, evaporators, coils, churns and floors; and process washes of butter, cheese, casein and other products.

Remedial measures may generally be classified as waste prevention, product utilization and waste treatment. The first two groups include the prevention of avoidable waste of milk solids and the processing and utilization of separated milk, whey and buttermilk into dry products, casein, albumin, lactose and stock feed.

The chief disposal and treatment methods in use today are dilution, irrigation, septic tanks, trickling filters, activated sludge and aeration. Dilution or irrigation are usually sufficient where plants are small and isolated or where stream flow is adequate. Trickling filters have been used, averaging 80 to 90 percent reduction in 5-day biochemical oxygen demand. Activated sludge and aeration are becoming more widely used. Biochemical oxygen demand removals by these processes can reach 80 to 90 percent or more.

an Industrial Waste Guide to the

Milk Processing Industry

Introduction

This publication represents the efforts of waste technologists and others of the Dairy Industry to develop a concise practical Guide for milk plant operating and design personnel. It emphasizes the appreciable reduction of waste which can be accomplished through waste prevention measures which can be carried out within the processing plant. Practical methods of carrying out such waste saving measures are thoroughly described.

The section on waste treatment was not intended to be a comprehensive discussion of dairy waste treatment. Sufficient information on waste treatment is included to suggest possible methods of solution to stream pollution problems which cannot be eliminated or adequately corrected by waste prevention procedures. Some performance data is presented on the more usual as well as the more recently developed milk waste treatment processes. This section will also serve to emphasize to milk plant supervisory personnel the value of waste saving methods in reducing total waste treatment costs.

Description of Process

Plants handling or processing milk and milk products may generally be classified as:

a. Receiving station.
b. Bottling plant.
c. Cheese factory.
d. Creamery.
e. Condensery.
f. Dry milk plant.
g. Ice cream plant.

The processes involved under each of these classifications are as follows:

Receiving Station

This is a collecting station for receiving raw milk from the farmers where it cannot be economically delivered directly to the processing plant. The milk is received in cans from the farmers, dumped into a weighing vat, sampled, cooled, and stored in tanks. The milk is then loaded into tank cars or tank trucks for shipment to the processing plants. Remaining operations are washing and sterilizing milk cans, vats, tanks, cooling equipment, and floors.

Bottling Plants

Raw milk and cream is received in cans, tank cars, or tank trucks. Process operations consist of can dumping, sampling, weighing, clarifying, filtering, preheating, pasteurizing, cooling, and filling glass or paper containers and metal cans with milk and cream. Other operations include washing of bottles, cases, cans, processing equipment and floors.

Cheese Factory

The raw material is whole milk, and in some cases, cream or separated milk. The intake milk is weighed, preheated, filtered, pasteurized, and cooled.

Cheese may be classified according to the kind of milk used, the process of making and the seasoning or ripening. Whole milk and separated milk, which may or may not be pasteurized, is run into vats and a "starter" (harmless lactic acid-producing bacteria) is added. The amount of "starter" used runs from 1 to 3 percent of the milk weight. The mixture is allowed to set and ripen at controlled temperatures until proper acidity has developed. Rennet, a substance obtained

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from the stomach of calves, is then added. This precipitates the casein from the whey, the process taking from 10 to 15 minutes at 86° F. The curd is cut by knives, piled and turned periodically (Cheddared) to release entrained whey. After draining and, in some cases, washing, the curd is put in press forms and placed under controlled temperature and humidity conditions for ripening and flavoring. In this process, the casein is peptonized and changed into forms that are digestible and the characteristic flavors are produced. For process cheese the ripened product is ground, melted, pasteurized to stop ripening, and packed while hot.

Creamery

Whole milk, sour cream and/or sweet cream are processed into butter and other products. When whole milk is received by the creamery, it is separated centrifugally into the cream fraction and the separated milk fraction. The separated milk may be processed into other dairy products for human consumption or for animal feed.

In the manufacture of butter, cream is pasteurized and ripened with selected acid- and flavor-producing organisms in preparation for the churning. The trade terminology for the bacteria culture used for the ripening process is "starter." The preparation of starter is carefully conducted and the quality maintained by competent bacteriologists. Cream, thus prepared, by pasteurization and ripening, is ready for churning. In the churning process, agitation of cream at low temperature, generally between 45° and 55° F., changes the type of emulsion from a fat-in-water phase to a water-in-fat phase. The minute globules of butterfat are surrounded by thin film. Agitation ruptures this film and permits the butterfat to coalesce. As this is done, butter granules, of a visible size, gather and trap small droplets of water in the fat. The butter is agitated in the buttermilk until such a time as the particles of butter are of the size of a small pea. At this time, the buttermilk is drained from the churn, collected and processed, either by condensing or by drying. The butter is washed, standardized for moisture and salt, "worked" until it becomes a uniform mass and then withdrawn from the churn for packaging and distribution.

Condensery

Whole milk, separated milk or other dairy products are evaporated to produce a concentrated product. Unsweetened evaporated milk is the product of this group in the largest production.

For the production of unsweetened evaporated milk, the whole milk is first preheated in a hotwell system in order to inactivate enzymes causing physical and chemical changes and to get desirable physical properties in the final product.

The heated milk is then evaporated either by batch evaporation, in which the evaporator is loaded and heat maintained until the charge reaches the desired specific gravity or by the continuous method, in which the milk flow through the evaporator is carefully regulated to produce a continuous discharge of product having the desired specific gravity.

The evaporator consists of a closed tank equipped with suitable heating surface. The source of heat is generally exhaust or low-pressure steam. A vacuum sufficient to cause the milk to boil at greatly reduced temperatures is maintained. Vapors are taken off through a top outlet and condensed by water or other cooling media.

After evaporation, the milk is homogenized, i. e., forced at high pressure through a closely set valve to break up fat globules and produce a fine suspension. Cans are filled and sealed by machine after which they are sterilized.

The sterilizing may be done on either a continuous or batch type of operation. The result is the same with either type in that the cans are fed into a retort of suitable size and construction and subjected to a temperature of 235° F. or more for a period of 15 to 25 minutes; then cooled by circulated water and removed. When dry, the cans are stored or prepared for shipment to market.

Sweetened condensed milk is produced in the same manner, except that sugar is added in the hot well. This product is evaporated to a higher specific gravity. Sterilizing after canning is not necessary since the sugar acts as a preservative. Other condensery products include condensed nonfat milk, whey and buttermilk.

Dry Milk Plant

Dry milks are produced from whole milk, nonfat or separated milk and buttermilk by one of the following methods:

(1) Atmospheric drum method: The milk is preheated or condensed as in the production of evaporated milk and then fed through perforated pipes

as a thin film to two steam-heated drums revolving toward each other. The regulated clearance between drums assures an evenly spread thin coating which dries quickly. The film is scraped off by a fixed knife and packaged for market.

(2) Vacuum drum method: A single drum revolves in a vacuum chamber. The preheated or precondensed milk is discharged to a delivery tray feeding the revolving drum. The drum picks up a thin film which quickly dries and is scraped off by a knife. This method allows drying at reduced temperatures.

(3) Spray method: The preheated or precondensed milk is atomized and sprayed into a current of heated air passing through the drying chamber, the solids falling to the bottom. Any solids carried off by the air are removed by passing the exhaust through some type of separator or other solids-removing process.

Clean-up washes and rinses of equipment, floors and receiving room complete the operations.

Ice Cream Plant

This is a plant where various milk and other products are received, combined and frozen into a finished product.

Ice cream and ice cream mixes are made from various formulas by combining cream, milk and milk products in definite proportions with flavor, sugar or other sweetening as required and a stabilizer. The mix is homogenized, pasteurized, and cooled. Fruits, nuts, or candies are then added and the entire mixture is frozen. After freezing, the resultant product is packaged and placed in hardening rooms for hardening and to await delivery.

Other operations are washing of cans, pasteurizers, tanks, coolers, freezers, packaging equipment, other miscellaneous equipment and floors.

Raw Materials and Products

The approximate composition of some common dairy products are shown in table MK–1. Ratios of products to raw material are shown in table MK–2.

TABLE MK–1.—*Approximate average composition and Biochemical Oxygen Demand (B. O. D.) of some common dairy products* [1]

Dairy product	Butterfat (percent)	Protein (casein and lactalbumin) (percent)	Milk sugar (lactose) (percent)	Added sugar (percent)	Ash (percent)	Acidity as lactic (percent)	Total solids (percent)	Organic solids (percent)	B. O. D.[2] (percent)
Whole milk [3]	3.9	3.2	5.1	0	0.7	.....	12.9	12.2	10.3
Evaporated milk	7.9	6.7	10.1	0	1.4	.....	26.1	24.7	20.8
Separated milk	.1	3.3	5.3	0	.8	.....	9.5	8.7	7.2
Nonfat dry milk solids	.9	36.9	50.5	0	8.1	.....	96.4	88.3	73.7
Sweetened condensed separated milk	.3	10.4	16.8	40	2.5	.....	70.0	67.5	50.2
Buttermilk [4]	.5	3.4	4.3	0	.7	0.6	9.5	8.8	7.2
Whey [5]	.3	.9	4.9	0	.6	.2	6.9	6.3	3.5
Cheddar cheese	35.5	26.6	1.5	0	3.5	.....	67.1	63.6	60.0
Cream	40.0	2.2	3.0	0	.4	.....	45.6	45.2	39.9
Ice cream mix	12.0	3.9	5.9	15	.8	.....	37.6	36.8	29.2

[1] Average from various sources.
[2] Percent B. O. D. = number of pounds of oxygen used by 100 pounds of product in 5 days at 20° C.
[3] Since the composition of whole milk varies considerably because of many factors, the values for individual samples may show considerable difference.
[4] Ripened cream buttermilk.
[5] American cheese whey.

TABLE MK–2.—*Ratio of products to raw material*

Process	Raw material	Products (pounds per pound raw material)
Separation	Whole milk (4 percent ± butterfat)	Cream, 0.12 (30 to 40 percent butterfat). Separated milk, 0.88.
Cheese making	Whole milk	Cheese, 0.10. Byproduct cream, 0.02. Whey, 0.88.
Do	Skim milk	Cottage cheese, 0.16. Whey, 0.84.
Butter churning	Cream (30 percent butterfat)	Butter, 0.37. Buttermilk, 0.63.
Do	Butterfat	Butter, 1.25.
Milk drying	Whole milk	Dry whole milk, 0.12.
Do	Nonfat milk	Nonfat dry milk solids, 0.086.
Do	Sweet cream buttermilk	Dry buttermilk solids, 0.093.

Sources and Quantity of Waste

Sources of Industrial Wastes

The industrial wastes from dairy plants consist of the water-borne milk solids which enter the drainage system. They may be classified according to their sources as follows:

1. Washing and rinsing of cans, equipment, and floors.
2. Spillage, freeze-on or overflow due to leaky or inefficient equipment and improper operation.
3. Entrainment from vacuum evaporators.
4. Unutilized buttermilk, separated milk and whey.
5. Spoiled raw or manufactured products.

Sources of Domestic Waste

Originates in the lavatories, locker rooms and laundries and is usually proportional in volume and strength to the number of employees.

Quantity of Industrial Wastes

The quantity of wastes discharged from industrial plants processing any particular material will vary widely, depending mainly upon the availability of water and management of water-using operations within the plant. This is particularly true of milk-products plants where rinse and wash waters of continuous flow operations may not necessarily be proportional to production; where cooling and condensing waters may or may not be recirculated in regenerative equipment; and where byproducts such as excess skim milk, whey and buttermilk may be discharged, contrary to approved methods, to the sewers.

Clean water from coolers, ice machines and other equipment and roof drainage are not usually considered wastes. This water adds to the volume of waste discharged, and unless it is segregated into separate drains will have its effect on treatment and disposal.

Composition of Wastes

The wastes consist, for the most part, of various dilutions of whole milk, separated milk, buttermilk and whey from accidental or intentional spills; drippings allowed to waste by inefficient processing equipment, methods or operations; washes containing alkali or other chemicals used to remove milk, milk products and partially caramelized material from cans, bottles, tanks, vats, utensils, pipes, pumps, hot wells, evaporators, coils, churns and floors; and process washes of butter, cheese, casein and other products.

Table MK–3 shows the most important processes in the dairy industry and the pounds of B. O. D. which can be expected in the material lost from each process with reasonably modern equipment and careful operation.

Because of the wide variation in individual cases, these figures should not be relied upon in the design of waste treatment facilities. They are given here to serve as a guide in cutting down losses within the processes where individual cases vary widely from the average. Further reductions of waste below these figures can be accomplished by proper waste-saving practices. The figures are representative of the ordinary wash wastes and process losses, not including byproducts, separated milk, buttermilk, or whey except the amounts included in normal cheese and butter washes.

TABLE MK-3.—*Approximate Quantities of B. O. D. in Various Process Wastes* [1]

Process	Pounds of 5-day B. O. D. per 10,000 pounds milk or milk equivalent [2]
Receiving and cooling milk	6
Tank-truck delivery to and from plant, including washing tank truck	1
Storage of fluid product in tanks	1
Evaporating whole milk, floor waste	2
Evaporating whole milk, entrainment loss	1
Canning and sterilising evaporated milk	2
Spray drying whole milk	1
Cream separating	2
Cream pasteurization, cooling and can filling	2
Separated milk pasteurization, cooling, and can filling	2
Cottage cheese or casein manufacture	16
American-cheese making, unwashed curd	10
American-cheese making, washed curd	16
Separated-milk condensing, plain, floor waste	3
Separated-milk condensing, plain, entrainment loss	0.5
Separated-milk condensing, sweetened, including barreling floor waste	6
Separated-milk condensing, sweetened, entrainment loss	0.5
Separated-milk condensing, superheated	12
Separated-milk drying, spray process	1
Separated-milk drying, roll process	16
Whey condensing, sweet, floor waste	8
Whey condensing, sweet, entrainment loss and volatile	2
Whey condensing, acid, floor waste	8
Whey condensing, acid entrainment loss and volatile	4
Whey drying, spray	5
Buttermilk condensing, floor waste	8
Buttermilk condensing, entrainment loss and volatile	4
Milk pasteurization, cooling and bottling (glass)	8
Milk pasteurization, cooling and bottling (paper)	6
Ice-cream-mix making, vat	4
Ice-cream-mix making, pan	4
Ice-cream freezing	0.5
Cultured-buttermilk making	5
Butter churning and washing	2

[1] Table adapted from "Waste Prevention in the Dairy Industry."
[2] "Milk equivalent" is the quantity of milk product or byproduct from one pound of milk.

Pollution Effects

Since milk wastes are organic in nature, the pollution effects are almost entirely due to the oxygen demand which they impose on the receiving stream. Fresh wastes may be acid or alkaline. Where receiving waters cannot provide sufficient oxygen for aerobic decomposition, the lactose is converted to lactic acid and the wastes become sufficiently acid to precipitate the casein. The heavy black sludge deposits and strong pigpen odors caused by the putrefying casein characterize milk-waste pollutions. The waters in sections of streams where the oxygen is excessively depleted are not suitable for certain uses and will not support fish life and in some cases may cause nuisance conditions.

Remedial Measures

The subject of milk plant wastes, with methods of recovery and treatment, has been extensively studied for years by State and Federal health agencies, experiment stations and individuals. Many of these developments have been incorporated in full-size treatment works for which results under actual operating conditions are available. For the purpose of this guide, such results have been used where available, to demonstrate the various types of treatment. Remedial measures may be classified as byproduct recovery or processing, waste saving and waste treatment.

Utilization of Dairy Byproducts

Dairy plant operators fully realize that the most important step in waste saving and waste disposal is the complete utilization of the milk solids so that no product containing milk solids has to be discharged to sewers and streams. Reference is made to table MK–1 which shows the organic solids content and the pollution resulting in pounds B. O. D. per 100 pounds of the most important dairy products.

Several important practical difficulties confront the dairy industry. The dairy industry's production is highly seasonal and most plants are small and cannot afford a large investment in some manufacturing equipment which will be used only during a small part of the year. It is also difficult to decide 1 or 2 years in advance which is going to be the most profitable type and outlet for milk solids, because milk product prices are influenced to a marked degree by competitive prices for other human food and animal feed ingredients.

The ideal dairy plant should be able to make any and all kinds of products so that it may attempt to realize the most satisfactory profit during any given period. Such a plant, however, would require extremely expensive installations with many kinds of equipment, some of which might be idle for months or years at a time. Consequently it becomes necessary to arrive at some reasonable compromise.

The three milk products which frequently are available in excess, especially during the flush season, are separated milk, buttermilk and cheese or casein whey. The principal uses for all three are: (1) direct feeding to livestock, (2) concentration by evaporation to condensed products which can be used either for human food or animal feed products, and (3) maximum concentrating by drying into dry products of milk, also used for human food and animal feed products. The dry products have great advantage in that they can be stored almost indefinitely under reasonable conditions without harm to their physical or nutritional properties.

The great need is for new and large outlets for products of milk. Preferably these should be in the human nutrition field, where the unique nutritional properties of milk products can be fully utilized and a fair price may be obtained in accordance with the nutritional value of these products.

In the industry, the trend is definitely toward more manufactured dairy products and fuller utilization of the total milk solids. However, there is a great deal of whey and buttermilk which continues to be wasted. Economical utilization of these products is largely determined by the availability of sufficient amounts within reasonably short hauling distances to justify the construction and operation of a central processing plant. Efforts are being made to expand the industrial utilization of milk and milk products, especially separated milk and whey. Essentially, this means trying to find new and more profitable uses for these products or their main constituents, namely, casein, lactose and whey proteins. At present, only insignificant amounts of these milk products or their main constituents are being used for industrial uses.

Some of the more common products that separated milk, buttermilk and whey can be utilized in are as follows.

Separated milk—plain condensed separated milk, sweetened condensed separated milk, nonfat dry milk solids, casein, paper coating, paints, plastics, fiber, adhesives.

Buttermilk—concentrated buttermilk, dry buttermilk solids.

Whey—pasteurized sweet whey, whey protein, dry whey, plain condensed whey, sweetened condensed whey, lactose riboflavin, ethyl alcohol, lactic acid, protein hydrolysates, whey cheese, primost or ricotta.

Waste Saving

The prevention or elimination of waste of milk fats and solids is an economical necessity for all dairy-product processors. The loss of milk fat and solids is costly. Unless avoidable wastes are eliminated a satisfactory profit cannot be maintained. In addition the treatment of waste is expensive. It is, therefore, worthwhile for every operator to study this problem and take appropriate action to prevent excessive waste in dairy products.

The saving of good milk and milk products now being wasted by flushing down the sewer will more than pay for any attention given to this problem. In

addition, it will materially reduce the amount of money it may be necessary to spend for waste treating equipment under wasteful methods.

Excessive waste originates from practically the same sources or is caused by the same thing in practically all dairy-processing plants. The following discussion deals with the more common origins and causes of such losses, and their means of correction.

Leakage and Drippage

The constant and continual loss of milk from improperly assembled or fitted sanitary lines, pumps, plate and tubular heaters and coolers, bottle fillers and, in fact, valves and connections on all dairy plant equipment is not uncommon. The volume and value of losses due to leakage is much higher than is generally recognized. One leak in itself, perhaps, is insignificant, but if leaks small or large are multiplied the loss becomes sizable.

Sanitary fittings provide a tight seal by means of ground joints or gaskets. Leakage occurs when the pipes are improperly assembled or when the ground surfaces have been damaged by careless handling. Rough or careless handling of valves, fittings and pipes destroys the smooth surface, or forces them out of round, making proper assembly impossible.

Leakage may occur on any piece of equipment where two component parts must be assembled either with or without a gasket. Pumps, homogenizers, plate and tubular heaters and coolers, vats and storage tanks are examples. *Again* it is necessary to see that good gaskets are used properly and that ground joints are kept leakproof.

Filling machines for cans, glass and paper bottles require care and attention to insure satisfactory operation without loss of milk. The valves must be properly assembled and kept in good condition to prevent waste.

Sanitary lines and pumps should be mounted high enough to allow placing of drip collecting pans under them if they start to leak. Repair of fittings and pumps is not always possible during operation. (Drip milk may be used as animal feed.)

Air leaks in pumps cause foaming of the milk products, and if this foam overflows from receptacles it carries away a considerable quantity of milk solids. Air leaks may occur on the suction line or through rotary seals or packing.

Overflow

The loss of milk due to overflow of cans, containers, vats, and tanks can be greatly reduced if not completely eliminated by adopting the necessary means to fit the particular situation.

Cans or small containers overflow readily because of their limited capacity. Therefore, they are not suitable for receiving milk or cream from a separator or direct from a vat or pump unless an attendant is always at hand. There is little or no economy in trying to utilize a 10-gallon can for receiving cream from a separator if the volume of cream is more than 10 gallons. Sooner or later heavy losses will occur.

Receiving tanks used in conjunction with weigh cans in the receiving room are limited in volume. The 3A Standards limit the maximum capacity of the receiving tank used with a single compartment weigh can to three times the capacity of the weigh can, but in no case shall it exceed 3,000 pounds. The maximum capacity of the receiving tank used with a double compartment weigh can shall not exceed twice the combined capacity of the two compartments of the weigh can, but in no case shall it exceed 3,000 pounds. Because of the limited capacity of the receiving tank and the rapidity with which milk is received, alarms and controls may not prevent overflow.

The safest, simplest, and most economical way to prevent overflow from receiving tanks is to provide a positive type pump for removing the milk. The pump should be kept in continuous operation when milk is received and its capacity must be capable of removing the milk as fast as it is received. Centrifugal pumps are not always suitable for this operation as they may lose their prime, become air bound and do not remove all milk from the receiving tank at the end of the day's run.

Storage and holding tanks, pasteurizing and cheese vats either have to be watched carefully or equipped with mechanical means to prevent overflow. Sanitary liquid level control devices to stop and start the pump or alarms which will notify the operator when the tank approaches the full point are recommended.

There are a large number of electronic control devices available to fit any size, shape or type of tank. They may be used to start and stop pumps, operate signal lights or alarms or open and close motorized valves and may be used on storage, holding and receiving tanks, pasteurizers, cheese vats, cooler troughs and any other receptacles in which milk is held.

Spillage

Loss of milk from spillage is largely due to careless handling. Plant employees must be made to realize the value of all dairy products lost as well as the difficulties encountered with waste treatment.

Freezing-on

Freezing-on of milk and milk products on coolers and freezers may be an important source of milk and milk product loss. Proper design of equipment with adequate refrigerant controls and proper operation will reduce these losses to a minimum.

For example, coolers of the direct expansion surface type should be designed so that the milk can be cooled to the desired temperature by a refrigerant whose temperature is not lower than 32° F. The cooler should be equipped with an automatic back pressure regulating valve to maintain a desired refrigerant pressure in the cooler and thereby control the refrigerant temperature. This back pressure regulating valve should be adjusted to maintain the pressure of the refrigerant in the cooler at or above the pressure equivalent to 32° F.

Piping a hot refrigerant gas line to a freezer will allow the use of hot gas to facilitate thawing frozen product and complete drainage at the end of the run.

Shutting off the refrigeration before the end of the run will also help in the prevention of loss due to freezing on of coolers as well as freezers.

Willful Waste

Perhaps the largest volume of milk solids entering the drainage system are put there more or less willfully or get there because no effort is made to save them. Buttermilk and whey should be handled as outlined under "Utilization of Separated Milk, Buttermilk, and Whey." These products should not be dumped into the sewer under any circumstances.

Residual Waste

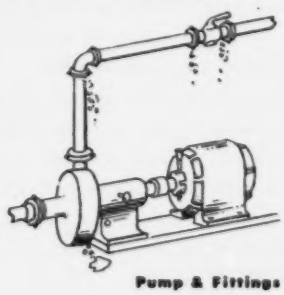
Residual waste is the milk or milk product which adheres to the surfaces of cans, tanks and processing equipment. The total losses may reach amazing proportions unless care is taken to see that these residuals are kept to a minimum.

Milk Receiving: Losses in the receiving room can be materially reduced by proper dumping of cans and by providing adequate time for drainage from the individual cans. In plants where such precautions are not taken, the loss may exceed 100 pounds for every 25,000 pounds of milk received.

The dumping of milk from the can into the weigh can should be done in a manner which will minimize loss of milk splash and provide maximum time for drainage of milk from the can. An easy way to accomplish this with a straightaway washer is to remove the cover from the can and place it in the washer, then invert the can onto the dump grid over the weigh can. Allow the can to remain in that position while the cover is removed from the next can and placed into the cover chute, then move the inverted can forward into the washer. This allows a few seconds for drainage of milk from the can which reduces residual losses approximately 50 percent. Grid dumping (Western style as described above) is preferred from a waste-saving standpoint.

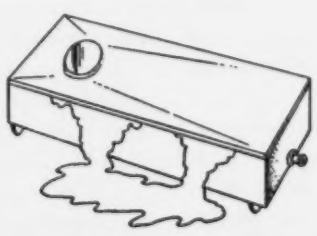
Milk continues to drain from the can after it is moved forward from the weigh can hopper. By means of an extension with a drip collecting pan at the entrance of the can washer, additional drain space is obtained and a large part of the residual milk is recovered. Additional milk can be recovered for animal feed by means of a volumetric spray nozzle which sprays the interior of each can with 3 or 4 ounces of water. These methods are recommended as a means to materially reduce the amount of milk and milk products that go into the drain.

LEAKAGE & DRIPPAGE



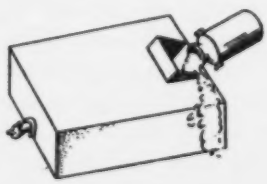
Pump & Fittings

OVERFLOW



Receiving Tank

SPILLAGE



Careless Handling

For handling cream cans, steam jets with can operated valves can be placed in the extension. The cans are emptied into the strainer hopper or forewarmer, but they are steamed to remove the residual cream and butterfat as they pass over the steam jets in the extension attached to the can washer.

In some cases the recovered milk or milk products may be utilized in products other than fluid milk, if the exterior of the can is clean and the extension is of sanitary construction. If conditions are such that the recovered milk becomes contaminated, it can be used for animal food. Local Health Department regulations should be consulted in regard to permissible uses of drip milk.

For handling fresh milk at least two drain positions are required and at least four positions are required for cream and concentrated milk products.

Milk Processing: Drainage of dairy products from sanitary piping, evaporators, storage tanks, pasteurizers and other receptacles adds considerably to the milk solids content of the waste. This is especially true where condensed products are concerned. Much of the drainage can be collected and saved, if the tanks and vats are properly located and the drainage line installed at the lowest point in the bottom of the tank.

Tanks with properly pitched bottoms and rounded corners will aid in this collection. Further savings may be effected by rinsing with a small quantity of water sprayed on the walls of the tanks. Sanitary lines should be properly pitched to accomplish complete draining before disassembly. Rinsing sanitary piping with a small quantity of water before disassembling will effect a greater saving. Sanitary containers must be readily available for collecting drainage and rinse. In one instance a small tank with pump and piping was so located as to allow the collection of the whole milk drainage. The collected milk was then conveyed to a point in the process where it could be used.

Butter Processing: Churns and butter printers should be kept in such condition that butter will not readily adhere to the surface. All butter should be carefully removed before cleaning.

Ice Cream Processing: Ice cream and ice cream mix are viscous, and if care is not taken losses may be considerable. Adequate time for complete drainage is necessary. Further savings can be made by using a small volume of water for rinsing the receptacles and catching the rinse.

Spray and Roll Driers: The dry milk solids in spray chambers are confined and a virtually complete collection is possible. However, loss may occur during packaging. Milk solid losses from roll driers can be larger due to free product which may accumulate on the floors. All dry products should be collected before washing by sweeping or vacuum cleaning.

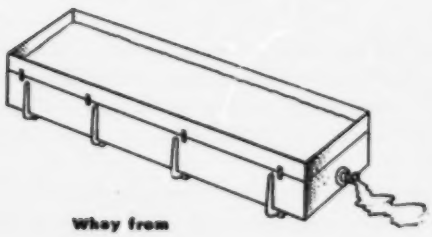
A milk solids savings program should include adequate facilities for collecting all dry milk solids. Too much emphasis cannot be placed on complete collection of the dry milk solids, since a very small amount will greatly increase the strength of the plant wastes.

Separators: Separators of the open type, which produce large quantities of foam, are a common source of loss of milk solids. Where it is necessary to prevent loss by foam these separators should be replaced by airtight equipment. Closed type separators are also preferred from the sanitation standpoint. It is important that gaskets be kept in good condition to prevent leaks.

Cheese Making: The cheese room can be a major source of milk solid losses. Considerable reduction in waste strength is possible by saving milk solids. Whey and cheese washings have a high B. O. D., and if allowed to escape the drain will materially increase the cost of waste disposal.

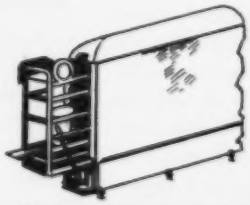
Cheese vats should not be filled higher than to within three inches of the top rim. If filled higher, cheese

WILLFUL WASTE



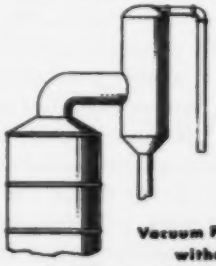
Whey from Cheese Vat

RESIDUAL WASTE



Cans Inadequately Drained before Washing

CARRY-OVER



Vacuum Pan without Entrainment Separator

and whey may be spilled over the rim and onto the floor during the mixing.

Ample capacity for handling whey should be provided. It is common practice to discharge the whey from the cheese vats into shallow open pans from which it is pumped to storage. The flow of whey is regulated manually and if the capacity of the pump is exceeded or the pump becomes air bound, the whey runs down the drain. Two improved methods of whey removal are outlined below:

A direct connection through a three-way valve may be made from the vat to the pump suction line. A removable screen is located in the vat over the end of the suction line to separate the cheese particles from the whey as it is removed.

A second method is to mount a small tank at the end of each cheese vat, so the top of the tank is at the same level as the top of the vat. A connection is provided from the vat to the tank, so that the whey enters the tank through a strainer. The whey is pumped directly from this tank. The strainer is removable so that the cheese particles which are retained can be returned to the vat.

The pump in both of the above methods should be a positive type. Centrifugal pumps lose their prime and are not satisfactory for this purpose.

Cheese hoops should be filled in the vat. Suitable containers should be located under each press to prevent press liquor from entering the sewer.

Carry Over

The vacuum pan, used for concentrating milk and its products, is an important piece of equipment in the dairy industry.

The vacuum pan cooling water is comparatively large in volume and may contain entrained milk solids which materially add to the losses in the plant and to stream pollution. Effective separators are available for installation on pans where entrainment losses are experienced.

Waste Treatment

In cases where prevention and byproduct recovery have been shown to be insufficient to correct stream pollution, a change in disposal methods or the installation and operation of waste treatment facilities will be necessary. Frequently, increased capital expenditures for waste prevention and byproduct recovery equipment are justified by the reduction in the cost of waste treatment facilities. The cost of separate waste treatment facilities will vary considerably because of climatic conditions, type of treatment plant designed and many local and other influencing factors. The cost will generally range from about $90 to about $140 for each pound of B. O. D. in the waste. This cost range is spread to cover ideal conditions where minimum expenditures are required, as well as those instances where difficult construction conditions are encountered or where rather extensive collection or outfall sewers are needed.

The possibility of discharging the residual wastes into a municipal sewerage system for treatment at the municipal sewage plant should be thoroughly investigated before embarking upon the design of separate waste treatment facilities. It is important that dairy plant officials discuss and reach agreements with both State water pollution control authorities and appropriate municipal sewage-treatment officials before making the final decision as to treatment and disposal of wastes. In general, the disposal of wastes into a municipal sewerage system has proven more satisfactory and economical than individual treatment.

Several methods of treating dairy wastes have been developed and investigated. At the present time, the most satisfactory means of dairy waste treatment are by use of aeration, activated sludge and biological filters. Activated sludge and aeration type plants do not, in most cases, require as large a capital investment as biological filters. However, operating costs of activated sludge and aeration plants are generally higher due to power requirements for supplying air. A brief discussion of these three methods is given below. Information on other treatment methods and additional information on the three methods discussed can be secured from the technical literature listed in the bibliography.

Aeration

Aeration differs from activated sludge in that the sludge developed is recirculated until stabilized, whereas in the activated sludge process the sludge is removed to digestion units for stabilization or disposed of otherwise.

Experiments conducted at Greenville, Ill., during 1951, indicated that the aeration type of treatment was capable of B. O. D. reduction up to 99 percent. It was

found that this type of treatment does not entirely destroy all of the solids produced. It is estimated that approximately 70 percent of the suspended solids in the mixed liquor was eventually destroyed and it was necessary to provide a sludge handling method for the remaining 30 percent. It was found to be important that the design of the plant be such that the sludge be kept continually in circulation and that no dead spots in which sludge could accumulate be permitted. It was also found that continual operation of the aeration facilities was necessary. These data indicated that the solids in the mixed liquor should be kept below 9 percent. The data also indicated that the installation of a waste equalization chamber ahead of the aeration process was desirable in order to level out fluctuations in strength of waste, volume of waste and alkalinity.

Aeration type plants treating waste from two cheese factories were found to produce B. O. D. reductions of 37 and 48 percent. These plants consisted of only an aeration tank with no means of sludge removal provided and were identical in construction.

An aeration type plant consisting of aeration, settling and sludge return and periodic sludge removal was found to operate on an efficiency of 85 percent.

A plant consisting of septic tank treatment followed by aeration with sludge settling was found to produce a B. O. D. efficiency of 96 percent.

A plant consisting of aeration, sludge settling and return and separate sludge storage was found to operate at an efficiency of 99.4 percent.

An aeration type plant for two small receiving stations has been quite successful. The treatment plant was originally designed for twice the present amount of waste, but losses have been reduced through waste prevention methods. The plant consists of an equalizing tank, aeration, settling and sludge return. B. O. D. removal was 92.7 percent.

Data on these plants are shown in table MK–4.

Biological Filters

Biological filters have proven to be adaptable to treating milk wastes. Suspended solids in the waste may cause difficulties through clogging. Preliminary settlement of the waste is desirable. However, filters are operating successfully without preliminary settling of the wastes. Studies on high-rate application and recirculation of part of the filter effluent have demonstrated the possibility of producing better treatment efficiencies and reducing the size of filter required. Although biological filters may not give as high efficiencies as well-operated aeration or activated sludge plants, they are often more economical to operate and do not require as close supervision. Biological filters are capable of producing B. O. D. removals of 75 to 90 percent.

Two high-rate milk waste treatment plants using dual type clarifiers and filters effect overall reduction of suspended solids and B. O. D. of 90 and 95 percent

TABLE MK–4.—*Operating results of aeration type waste treatment plants*

Type of plant	Waste volume gallons per day	Raw 5-day B. O. D. pounds per day	Aeration tank cubic feet per pound 5-day B. O. D. per day	Air supply cubic feet per pound 5-day B. O. D.	Percent of 5-day B. O. D. removal
CHEESE FACTORY WASTES					
Aeration only	7, 600	125	9	575	37
Do	3, 550	95	12	760	48
Aeration, settling, sludge return, periodic sludge removal	9, 500	179	19	2, 000	85
Septic tank, separate aeration, recirculation through septic tank, settling in second septic tank	10, 250	213	12	950	96
Aeration, settling, sludge return, separate sludge storage	17, 200	108	27	1, 870	99. 4
RECEIVING STATION WASTES					
Equilization tank, aeration, settling, sludge return	8, 900	17. 5	115	5, 760	92. 7

respectively.[1] Results at these two plants were given as follows:

		Plant A	Plant B
Flow, G. P. M.		21	31
Recirculation	Primary	3.52	1.26
	Secondary	4.52	2.23
Total solids (p. p. m.)	Raw	1,211	1,182
	Primary effluent	517	781
	Final effluent	461	712
Suspended solids (p. p. m.)	Raw	363	330
	Primary effluent	91	61
	Final effluent	36	31
B. O. D. 5-day (p. p. m.)	Raw	648	533
	Primary effluent	96	38
	Final effluent	33	20

Activated Sludge

Activated sludge treatment is less elastic and shock proof than aeration or trickling filters. It has the advantage over trickling filters, in that suspended solids or readily flocculated substances in the raw wastes do not interfere with operations. Biochemical reductions of 90 to 95 percent can be obtained with activated sludge type plants.

Activated sludge is reported to be successful at a plant consisting of a receiving tank, air lift, lime feed, mixing chamber, primary settling tank, aeration basin, and final settling tank.[2] The pH is maintained at 8 to 9 in the mixing chamber by use of lime to neutralize the lactic acid and precipitate casein in the primary tank. The sludge settled in the primary tank is trucked away and spread on land, where it is plowed under. The formation of lactic acid in the aeration basin reduces the pH to 7.6–7.8. The final sludge is recirculated to the aeration chamber. Typical operating results at this plant are reported as follows:

	5-Day B. O. D. (p. p. m.)	Total solids (p. p. m.)	pH
Raw waste	545	797	7.2
Final effluent	7.4	466	7.7
Percent reduction	98.4	41.5	...

[1] Fischer, A. J. "Dual Clarifier and Filter Structures Simplify High-Rate Treatment Process." CA 41, 7025 f. (1947), R. B. Thompson, *Engineering News-Record*, 139, 64–6 (1947).

[2] Montagna, S. D. "The Treatment of Dairy Waste." *Sewage Works Journal*, 12,108 (1940).

Two successful activated sludge treatment plants were recently installed.[3, 4] The first plant consists of two aeration tanks in series and one hopper bottom final settling tank. All settled sludge is returned to the head end of the aeration tank, next to the raw sewage inlet, by means of an air lift. The second treatment plant consists of one aerated holding tank from which the waste is pumped through a division box to the aeration tank. From the aeration tank it flows through the final settling tank to the outfall sewer. All settled sludge is returned to the head end of the aeration tank by means of an air lift. At both of these installations all the uncontaminated water is handled through separate clear-water sewers and does not go to the waste treatment plant.

Physical characteristics of these two plants and a summary of the operating results are shown in the following table:

OPERATION DATA

	Plant A	Plant B
24-hour flow—gallons per day	4,400	7,200
Hours of flow per day	8	7
Holding tank volume—gallons	.....	3,420
Aeration tank volume—gallons	7,460	12,300
Settling tank volume—gallons	484	970
Aeration time—hours	39.4	41.2
Settling time—hours	2.53	3.22
Average rate of flow—G. P. M.	10.5	15.0
Equalized rate of flow—G. P. M.	.....	5.0
B. O. D. raw waste—p. p. m.	567	926
B. O. D. holding tank effluent—p. p. m.	.....	673
B. O. D. final effluent—p. p. m.	19	31
Rate of sludge return—G. P. M.	20	25
Air supply—C. F. M.	85	100
Air per gal.—cubic feet	27.8	20
Cubic feet air per pound B. O. D. raw waste	5,880	3,570
Cubic feet air per pound B. O. D. removed	6,070	3,750

[3] *New Design for an Activated Sludge Plant to Treat Milk Wastes*, Paul M. Thayer, page 171, Proceedings of the Sixth Industrial Waste Conference, February 21–23, 1951, Engineer Bulletin, Series No. 76, Purdue University.

[4] Designated activated sludge plants by the author, but very similar to aeration-type plants as defined in this publication.

Chemical Oxygen Demand (COD) Test For Milk Waste Samples

There is need for a test which will supplement the B. O. D. test, but which will give results within a short period of time. Such a test will be of value in the control of waste treatment plants and during the waste prevention program.

Numerous tests have been tried for this purpose, but the one which now shows the most promise is given below. It is not meant to supplant the B. O. D. test, which at this time is the generally accepted procedure for most accurately evaluating milk waste strengths.

It is believed that because of more immediate results, the COD test is a practical control test for many dairy plants.

Reagents

1. Dichromate oxidizing agent. Carefully mix 500 ml. concentrated sulphuric acid and 500 ml. 85 percent ortho-phosphoric acid. Dissolve 2.5 grams of C. P. potassium dichromate in the mixture. This will take some time to dissolve but will finally go completely into solution.

2. Dissolve 50 grams of sodium iodide in 200 ml. of distilled water.

3. Sodium thiosulphate 0.05N. Dissolve exactly 12.41 grams sodium thiosulphate crystals in 1 liter of distilled water.

4. Soluble starch solution.

Apparatus

Six 500 ml. Erlemeyer flasks.
Two 50 ml. volumetric pipettes.
Two 10 ml. volumetric pipettes.
Four 10 ml. Mohr pipettes.
One electric hot plate (large enough for 6 flasks).
Six glass thermometers 0–250° C.
Two 25 ml. glass stoppered burettes.
One dropping bottle for starch solution.
One 250 ml. graduated cylinder.

Procedure

1. Pipette exactly 50 ml. of dichromate solution into each of the desired number of 500 ml. Erlemmeyer flasks. (Use volumetric pipette.) (Blank and waste samples should be run in duplicate.)

2. Add 5 ml. distilled water to each of two flasks as blanks and exactly 5 ml. of each waste sample to each of two flasks. Use separate Mohr pipettes for each sample. The water and waste samples should be added to the dichromate slowly with stirring.

3. Place the flasks on the heating element (electric hot plate preferred but gas burners can be used) and suspend a thermometer (about 250° C.) in each flask.

4. Heat as uniformly as possible so that a temperature of 170° C. is reached in from 5 to 6 minutes. Above this temperature the mixture starts to decompose as indicated by fumes in the flask above the liquid.

5. Immediately remove the heat and the thermometers and cool as rapidly as possible under water,* cooling the duplicates at the same time. The mixture should be almost to room temperature in about 5 minutes.

6. Add 200 ml. of distilled water to each flask with constant mixing. Use graduated cylinder. Cool to room temperature under water.

7. Add exactly 10 ml. of sodium iodide solution rapidly to one flask with constant mixing. Use volumetric pipette. Titrate immediately with 0.05N thiosulphate adding starch near the end of the titration. The last few ml. of thiosulphate should be added drop by drop with constant mixing since the end point is not sharp and the reaction slow. The end point is from dark blue to a pale blue green.

Note.—Titrate each flask before adding the iodide to subsequent flasks since iodide is lost on standing.

Calculations

Total oxygen demand p. p. m. = (ml. thiosulphate in blank − ml. thiosulphate in sample) × 80.0.

*Rotate flask in a bath of cold water to cool.

Bibliography on Milk Wastes

Industrial waste guides, Ohio River pollution control. Appendix VIII of supplement D. Milk. USPHS House Doc. 266, 78th Congress, 1st Session, 1034 (1943).

Anon., *Waste prevention in the dairy industry.* A report of the Waste Disposal Task Committee of the Dairy Industry Committee (Feb. 1950).

Agar, C. C., *Milk wastes,* part of Forum on Ind. Waste Problems, 22d Ann. Meeting, FSWA, Boston, Oct. 1949, SIW 22, 6, 777 (June 1950).

——— *Practical methods of preventing dairy waste nuisance.* SWJ 10, 115 (1938). CA 32, 3841 (1938) W. D. H.

Backmeyer, D. P., *Disposal of condensed milk by digestion.* SWJ 21, 6, 1076 (Nov. 1949).

——— *Disposal of cheese whey by digestion.* SWJ 20, 1115 (1948).

Barritt, N. W., *The treatment and disposal of milk factory effluents, I. By means of percolating filters and septic tanks.* J. Soc. Chem. Ind., 55, 48, Trans (Mar. 6, 1936).

Bloodgood, D. E., *Milk waste disposal.* SWJ 20, 695, 707 (1948). CA 42, 8986a (1948) W. D. Hatfield.

Eldridge, E. F., *Industrial waste treatment practice.* McGraw-Hill Book Company, 1942.

— —— *Milk waste treatment by the Mallory process.*

Water Works and Sewerage, 88, 457 (Oct. 1941). CA 36, 6009 (1942).

——— *Dairy wastes disposal.* SWJ 21, 4, 668 (July 1949).

——— *Oxidized sludge and regenerative digestion treatment plant at Zeeland, Michigan.* Michigan State College Engineering Experiment Station Bulletin No. 94 (1942).

Fischer, A. J., *Dual clarifier and filter structures simplify high-rate treatment process.* CA 41, 7025f (1947) R. E. Thompson. Eng. N. R. 139, 64–6 (1947).

Gloyna, E. F., *Milk waste treatment on an experimental trickling filter.* Water and Sewage Wks. 97, 11, 473 (Nov. 1950).

Halvorson, H. O., *Aero-filtration of sewage and industrial wastes.* Water Works and Sewerage, 83, 307 (Sept. 1936).

Harding, H. G., *Industrial Waste Symposium—Dairy Industry.* Ind. Eng. Chem., 44, 3, 487 (1952).

Hauer, G. E., *Successful Treatment of Dairy Waste by Aeration.* SIW 24, 10, 1271 (Oct. 1952).

Horton, J. P., Trebler, H. A., *Recent Developments in Design of Small Milk Waste Disposal Plants.* SIW 25, 8, 941 (Aug. 1953).

Johnson, W. S., *An aeration plant for milk waste disposal.* Abs. SIW 22, 8, 1093 (Aug. 1950) W. A. Hasfurther, Eng. Bull. 33, 4, 54 Ext. Series No. 68, Purdue Univ. (July 1949).

Kirchoffer, W. G., *Casein wastes treated on trickling filter at Richland Center, Wis.* CA 35, 19125 (1941) M. S. Agruss. Sew. Wks. Eng. 11, 496–7 (1940).

Levine, M., *Biological purification of creamery wastes.* SWJ, 4, 2, 322 (Mar. 1932).

McKee, F. J., *Milk waste treatment by aeration.* SIW 22, 8, 1041 (Aug. 1950).

Muers, M. M., *The biological purification of whey solutions.* J. Soc. Chem. Ind. 55, 71, Trans. (Mar. 20, 1946).

Neill, D. G., *Waste treatment facilities of the Belle Center Creamery and Cheese Company.* Abs. SIW 22, 8, 1093 (Aug. 1950) W. A. Hasfurther. Eng. Bull. 33, 4, 45 (Ext. Series No. 68) Purdue Univ. (July 1949).

Oeming, L. F., *Milk-waste treatment at the Detroit Creamery Company Condensery, Ovid, Mich.* SWJ 20, 512 (1948). CA 42, 8985 i (1948) W. D. Hatfield.

Pennsylvania Sanitary Water Board. *Standards for treatment of wastes from milk plants adopted by the Sanitary water board at its meeting on December 17 and 18, 1947.* Mimeograph.

Porges, N., Pepinsky, J. B., Handler, N. C., Hoover, S. R., *Biochemical oxidation of dairy wastes. I. Method of study.* SIW 22, 3, 318 (Mar. 1950).

——*Bio-chemical oxidation of dairy wastes. II. Comparative study of yeasts.* SIW 22, 7, 888 (July 1950).

Ruf, H., Warrick, L. F., *Milk waste treatment studies in Wisconsin.* SWJ 6, 580 (1934).

Sanders, M. D., *Industrial sanitary engineering in dairy plant management.* Abs. SIW 22, 8, 1093 (Aug. 1950) W. A. Hasfurther. Eng. Bull. 33, 4, 64 (Ext. Series No. 68) Purdue Univ. (July 1949).

Schwarzkopf, V., *Reduction of Milk Wastes in Dairy Plants.* SIW 24, 12, 1489 (Dec. 1952).

Trebler, H. A., Harding, H. G., *Industrial wastes—dairy industry.* CA 41, 4259b (1947) Foster Dee Snell. Ind. Eng. Chem. 39, 608–13 (1947). Abs. SWJ 20, 594 (1948) H. G. Swope.

—— *Dairy waste disposal,* Chem. E. Prog. 43, 5, 255 (May 1947). CA 41, 3895b (1947) C. L. Mantell.

—— *Two-stage, high-rate trickling filters for dairy waste treatment.* Abs. SIW 22, 8, 1093 (Aug. 1950) W. A. Hasfurther. Eng. Bull. 33, 4, 67 (Ext. Series No. 69) Purdue Univ.

Uhlmann, P. A., *Charges to industries for treating their wastes in a municipal plant.* Pub. Wks. 75, 12, 23 (Dec. 1944).

Wilson, M. A., *High-rate filters treat creamery wastes.* Sewage Works Engineering, 17, 6, 309 (June 1946).

Zack, S. I., *Treatment and Disposal of Milk Wastes.* SIW 25, 2, 177, (Feb. 1953).

For a more extensive bibliography containing 194 references, see the article in *Sewage Works Journal* 20, 707 (1948) by D. E. Bloodgood.